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August Energy Figures Released

40100072a Beijing CEI Database in English 27 Sep 89

[Text] Beijing (CEI)—Following is a list of China's total output of primary energy production in August 1989, released by CSICSC [China Statistics Information Consultancy Service Center]:

Item	Unit	1-8/89	8/89	Percentage over 1-8/89
Total output (10,000 tons of standard coal)		64,692.0	8,639.0	106.77
A. Raw coal	10,000t	66,119.0	8,833.0	108.39
Including:				
Output under unified central planning	10,000t	31,217.0	3,982.0	105.52
B. Crude oil	10,000t	9,066.9	1,175.6	100.79
C. Natural gas	100 million cubic meters	99.95	12.70	104.32
D. Hydropower	100 million kWh	789.0	119.3	110.13

R&D of Power System Relaying Reviewed

40130129 Beijing DIANLI XITONG ZIDONGHUA [AUTOMATION OF ELECTRIC POWER SYSTEMS] in Chinese Vol 13 No 2, Mar 89 pp 20-24

[Article by Li Musong [2621 1970 2646] of the Nanjing Automation Research Institute: "A Review of the Development of Electric Power System Relay Protection in China and R&D Development Work at the Nanjing Automation Research Institute [NARI]"]

[Excerpt] [Passage omitted]

I. Brief Review

Shortly after the nation was founded, China's electric power departments mainly used several simple protection relays previously imported from GE and Westinghouse in the United States, GECM in England, Japan, and other countries. At the time, China had only a few plants producing simple intermediate relays and contacts. In the 1950's, the newly built Acheng Relay Plant imported protection technologies and equipment from the Soviet Union to form China's only power grid protection manufacturing plant. At the same time, several private plants which combined to establish the Shanghai Relay Plant continued to copy simple foreign electromagnetic relays. In the late 1950's, the 110 to 220 kV Northeast China Grid imported Soviet-made protection equipment and Soviet experts came to work in northeast, north, and other areas of China. They played a role in promoting the development of power grid protection technologies and specialized personnel training in China. Up to now, this generation of Chinese relay protection experts who are active in operation, design, scientific research, education, and other departments grew up in practice during this period and afterward. In the late 1950's, China's power grid relay protection workers began to develop their own new types of circuit protection. In the difficult conditions of the 3-year period of difficulty [1959-1961], the North China Electric Power Design Academy resolutely developed and improved rectifier range protection devices, finalized the design, and began producing them at the Shanghai Relay Plant in the mid-1960's. This was the first high voltage grid complex protection developed and produced independently in China. With substantial assistance from operation and design units, rectifier grid protection quickly replaced induction protection copied from the Soviets and was extended and applied throughout China. The Shanghai Relay Plant also became one of China's main relay protection producing plants.

In the mid and late 1960's, construction of a 330 kV power grid began in northwest China. Design and scientific research units in north and northwest China began cooperating in attacks on key topics to develop a full set of crystal tube high voltage power grid protection devices. Through cooperation by scientific research units and the relevant institutions of higher education and operation units, in the extremely difficult circumstances of the 10-year period of chaos, a full set of circuit protection devices was provided for the 330 kV project in a successful key step in developing from electromechanical to static protection. Subsequent design finalization and production startup for 220 kV full set circuit protection indicated that power grid protection in China had entered the era of electronic technology. At the same time, the Nanjing Electric Power Automation Equipment Plant also grew into China's biggest static power grid protection manufacturing plant.

In the late 1970's, under leadership by the Ministry of Water Resources and Electric Power, scientific research, design, and operation units began to attack key problems in developing 500 kV ultra-high voltage power grid protection equipment and put it into operation smoothly in northeast and north China in an excellent situation. They also quickly began to develop integrated circuit protection using advanced microcomputer technology. In 1985, NARI successfully developed China's first set of integrated circuit range protection and placed it into trial operation in the 500 kV Northeast China Grid. It passed ministry-level inspection in 1986. This was an important milestone in the history of power grid protection technology development in China. It indicated that China's electric power system relay protection technology had entered a new era of microelectronic technology and that a structural design model in effect for 20 years had passed.

Implementing the policy of opening up to the outside world and ending the long period of closing off the nation in the late 1970's greatly promoted expert and scholarly exchanges in relay protection in China and foreign countries. Yang Jixun [2799 1142 6676] of the North China Electric Power Academy earned the first Ph.D. in relay protection in China, and he successfully developed China's first digital range protection system using microcomputer technology to inaugurate the era of concentrating all forces in institutions of higher education to develop microcomputer protection.

The Science and Technology Department of the Ministry of Water Resources and Electric Power pointed out in 1987 that China's power grids have accumulated valuable experience in operation, design, scientific research, manufacturing, and other areas over the past 30-plus years and created a large group of our own experts. Moreover, our experience in inspecting, accepting, and operating protection imported from foreign countries has confirmed that Chinese-made power grid protection equipment is better suited to our national conditions and is fully capable of competing with international brands. With substantial assistance from operation, design, and construction departments, NARI participated in bidding on system protection for the Tianshengqiao 500 kV transformation project and is now in intense competition with eight famous power grid protection manufacturing plants and businesses in the United States, Japan, France, Sweden, Switzerland, and China. They have overall contractual responsibility for protection, for wave recording, and range measurement. This was the first victory for a Chinese unit in bidding for large-scale relay protection projects, and it indicates that the era of the monopoly of foreign businesses in international bidding for 500 kV in China has ended.

All of China's power grids have now decided to eliminate rectifier and crystal tube discrete components in high voltage power grid protection, which indicates that power grid protection in China has entered the era of high technology and microelectronic technology.

II. Advances in Power Grid Protection Technology in China

Construction and development of the national economy over the past 30-plus years has brought considerable progress to the electric power industry and it has continually placed new demands on electric power system protection technology. In the late 1970's, the S&T Department of the Ministry of Water Resources and Electric Power organized and led attacks on key topics in 500 kV power grid protection. This involved detailed systems research on all aspects of basic theory, system characteristics, and basic requirements, and it provided a solid foundation and concrete demands for developing ultrahigh voltage power grid protection technology in China. Substantial growth of advanced microelectronic technology and development of new types of protection using advanced microelectronic technology have provided realistic possibilities.

China's manufacturing plants which specialize in power grid protection have now grown from the single Acheng Relay Plant in the 1950's to several large and medium-sized plants at fixed sites including Acheng, Xuchang, Nanjing, Shanghai, Baoding, Beijing, Zunyi, and others. They can provide all types of primary protection, reserve protection, and automated equipment required in all grades of high, medium, and low voltage power grids. Compared with protection equipment of foreign plants and businesses, excluding the need to work to improve manufacturing technology quality, the weak relationships among China's power grids and strict operating conditions have enabled the principles and technical performance of Chinese-made protection to adapt better to China's national situation and needs. The level of software technology in China's power grid protection technology has been acknowledged by both Chinese and foreign relay protection circles.

At present, power grid protection is basically matched up in China's high voltage integrated circuit power grids. This is particularly true of product series already formed by NARI which are now being produced in batch quantities.

1. Range protection devices. These are characterized by the use of MHO disks and quadrangles. They have combined inter-phase and ground range as well as independent inter-phase or ground range protection. Besides indicating static breakdown variables, a new type of rapid range protection device also can indicate working frequency variation variables. Some range protection has been fitted with zero sequence current direction protection to meet the needs of different users, and it can satisfy problems with high ground resistance breakdown protection.

2. Vertically integrated protection equipment. This has grown from a single product variety of phase difference protection copied from the Soviets in the 1950's to different series including directional comparison and phase comparison. Some is capable of indicating static variables and has rapid direction protection based on working frequency variation variable principles with technical performance at advanced international levels. Besides that suitable for use in regular high voltage power grid protection, we also have rapid directional protection suited for dual loops on the same pole and other special patterns.

In the PILOT pattern, we have developed from the single sealed type of 30 years ago to exclusive, removed exclusive, allowable (out-of-range and inadequate range patterns), and all other patterns.

For channels used, besides conventional PLC channels (special and multi-purpose communications), we also have rapid direction protection product varieties suitable for fiber optic channels or microwave channels.

3. High voltage power grid rapid protection for short lines and ultra-short lines, particularly operationalization of fiber optic longitudinal differentials, has solved the problem of short line and ultra-short line protection in high voltage power grids. Besides integrated fiber optic longitudinal differential protection product varieties, we also have split-phase longitudinal protection. At the same time, we also have extended integrated circuit range protection suitable for use in short lines.

4. All types of automated reclosing. Overvoltage and short lead-wire protection, circuit breaker breakdown protection, operating boxes, and various other types of matching protection equipment suited for dual bus-bars and single half-switch junctions are now completely integrated and can meet the needs of all grades of power grids.

5. Microcomputer technology wave recording and range measurement equipment are now being produced and supplied, and we have extended dual-function wave recording and range measurement equipment.

All these types of power grid protection equipment use linear and digital integrated modules with stable and reliable performance. Much of the equipment is also matched with operation and experiment components which have long-term monitoring and self-diagnosis measures like new types of rapid direction, rapid range, and other protection which are also matched with special purpose fixed value inspection loops that have significantly improved reliability and greatly reduced the amount of operation maintenance and debugging work, with good evaluations by operation units.

As large power grids developed, great strides were made in grid safety control in the 1980's. Large-scale hydro and thermal power station safety control using microcomputers and regional power grid safety control equipment have continued to appear. Step-out disconnect and power measurement differentiation equipment has now entered the system and some is playing an important role. Power grid safety control, an important field in power grid protection, has received attention from power grid management departments at all levels and is developing quickly.

Microcomputer protection is also developing rapidly in China, and the first set of microcomputer range protection developed by Professor Yang Jixun has passed inspection and gone into operation. Shanghai Jiaotong University, Tianjin University, Central China Science and Engineering University, Xi'an Jiaotong University, Qinghua, and other institutions of higher education are now doing a great deal of R&D. Besides the microcomputer range measurement equipment which it extended some time ago, NARI's microcomputer wave recording has been accepted and gone into operation and China's first microcomputer main transformer protection has gone into normal operation in the electric power system. Microcomputer range protection also has entered dynamic model experiments, and new products will be extended during 1989.

To achieve a fundamental change in the backward situation in China's electric power system protection equipment debugging, besides experimental microcomputer equipment successfully developed by Tianjin University, NARI successfully developed a 6-circuit programmable signal source. Not only can the current and voltage base wave of each phase be controlled, but one can also arbitrarily superimpose higher-order harmonics, and the phase amplitude can be keyed in. A microcomputer debugging equipment series suitable for power grid protection experiments at all levels in China will be extended in 1989.

III. Undertaking Scholarly Activities in Relay Protection

The 10-year period since the late 1970's was a decade of breakthrough progress in relay protection technology in China as well as a decade of unprecedented vitality in relay protection scholarly activities in China. The development of national and provincial-level relay protection scholarly activities is one fundamental reason for the major progress technologically.

Since the 2d Relay Protection Symposium of the China Electrical Engineering Society in 1979, the regularly scheduled convening of the National Relay Protection Symposium has invigorated the academic atmosphere and promoted improvements in scholarly levels and advances in scientific research work. Relay protection has been upgraded from a special subcommittee under the Systems Specialization Committee in the China Electrical Engineering Society to a national special committee. Big achievements also have been made in relay protection scholarly activities in the various provinces. The electrical engineering societies of Jiangsu, Zhejiang, and Anhui also convened a joint relay protection symposium in 1988. At the same time, relay protection special committees at all levels have reinforced continuing education and personnel training and held national, provincial, and regional study courses and research courses which have played a significant role in extending new technologies, training personnel on the job, and improving operating levels. The achievements of relay protection societies at all levels have been affirmed and praised by the China Electrical Engineering Society and the Ministry of Energy Resources (Ministry of Water Resources and Electric Power).

During this decade, over 20 scholarly papers on relay protection have been presented at the IEEE, CIGRE, IFAC, and other international societies, and one received a superior paper award from the IEEE. China's progress in power grid protection technology and the level of China's experts are receiving increasing attention from international academic circles.

IV. The Tasks Facing Power Grid Protection in China

China can now supply sets of microcomputer protection which use integrated circuit microelectronic technology and some components required for all grades of high voltage power grids, but the product variety is not complete. Further improvements should be appraised for same-pole dual-loop and other special protection. We also have been forced to spend enormous sums of foreign exchange to import certain products we temporarily cannot produce in China from foreign countries. We do not blindly oppose all imports of foreign protection. It is entirely necessary that we import protection with advanced performance from foreign countries to study advanced technology, reduce the differential between China and advanced international levels, or fill in blank spots. In the past few years, performance experiments and operation practice with protection equipment imported from ASEA, GE, BBC, Siemens, and other companies have confirmed that foreign protection products are not entirely suited to China's national conditions. According to incomplete statistics, more than $30 million in foreign exchange was spent to import protection from foreign countries during the Seventh 5-Year Plan. In the past few years, the State Council Major Projects Office, State Science and Technology Commission, and Ministry of Energy Resources (Ministry of Water Resources and Electric Power) decided to focus on matching up and extended application of Chinese-made integrated circuit power grid protection. For this reason, we must fully utilize China's rich experience in the field of relay protection and rely on specialists in China's operation, design, and scientific research units, institutions of higher education, and manufacturing departments to move China's power grid protection technology and equipment up to a new level and enter market competition. To implement this policy of the higher authorities, we should truly focus on standardization and modularization, and accelerate product matchup and design and extended application of typical screens. Manufacturing plants should make significant efforts at fundamental improvements in technology and reinforce quality assurance systems to change the present situation in China of power grid protection hardware that is backward compared to software and equipment manufacturing that is backward compared to functional design. We should strive to enter international markets as quickly as possible.

Many operation and management departments pointed out the question of rational model selection and rational configurations in power grid protection some time ago. Assistant chief engineer Wu Yunxiang [0702 6663 4382] in the Anhui Provincial Electric Power Bureau has pointed out in several papers that we should rationally determine choices and configurations for protection equipment in all grades of power grids according to grid requirements, product characteristics, personnel quality, and other factors. He also pointed out in his article "Selecting 220 kV Line Protection" (see 1988 NIAN ZHE-SU-WAN SANSHENG JIDIAN BAOHU XUESHU NIANHUI LUNWEN XUANJI [Collected Articles From the 1988 Annual Zhejiang-Jiangsu-Anhui Relay Protection Symposium) that selection of the type of protection concerns grid safety. In high voltage power grids, it is no longer appropriate to select discrete component protection. Because it employs digital and linear integrated circuits and self-diagnosis systems, the reliability of integrated circuit protection is much greater than crystal tube protection, the performance is more stable, and debugging and maintenance are more convenient. Some integrated circuit protection like CKF-1 rapid directional protection have prominent performance and are not inferior to present microcomputer protection:

1. Fast operating speed;

2. Strict circuit design that is safe and reliable;

3. Weak power sources and single test power sources can be used;

4. Working frequency abrupt variation principles, no load effects, etc. (Author's note: Besides the above characteristics and not being subject to the effects of system oscillation, there is another prominent advantage: the allowable breakdown ground resistance is great, exceeding the performance of all types of Chinese and foreign directional protection at the present time.)

Because integrated circuit protection and microcomputer protection each has its own advantages, we should select the advantageous and reject the disadvantageous and use each to complement the other. Moreover, it is not reasonable to skip the integrated circuit protection stage entirely at the present stage.

The overall situation in the developed nations which developed microcomputer technology and an electric power industry before China is about the same. In the United States' main 765/500 kV grids, all the main protection is integrated circuit protection with electromagnetic (inductive) backup protection. Additional current direction protection is also in operation for range protection. This situation deserves our attention.

At present, we should expand production capacity for integrated circuit power grid protection and improve technological quality, and we should speed up completion of product sets and the design and production of finalized design screens to provide the electric power industry with a replacement generation of products to replace the discarded rectifier and crystal tube protection.

R&D on microcomputer protection should select the advantageous and reject the disadvantageous, make full use of the potential of microcomputer technology, and not superficially pursue 100 percent digitalization. Another issue which deserves mention is that microcomputer protection should not stop at the principle of analog protection but should prevent microcomputer protection from becoming a simple "translated" method of analog protection. Given China's present situation, this issue deserves particular attention.

Back at the end of 1987, Professor Yang Jixun pointed out that the CPU's used in Chinese-made microcomputer protection have been continually upgraded from 8 bit to 16 bit and on to 32 bit. If we work only in this area, redundancy will decrease, reliability will be degraded, prices will rise, most of the potential of the microprocessors will not be utilized, and the performance/price ratio will become worse, which is not the best thing. We should give attention to using single-board computers with multiple channels, multiple CPU's, and a high performance/price ratio. The North China Electric Power Academy is now involved in this type of work and some foreign scientific research and manufacturing units have taken a step, which should receive our attention.

China had a breakthrough in integrated circuit protection which can provide better performance than rectifier and crystal tube protection. In the 1970's, the Science and Technology Department of the Ministry of Water Resources and Electric Power organized basic theoretical research on 500 kV output circuit protection and played a significant role. To take advantage of microcomputer technology, we must reinforce research on protection principles, computing methods, and a whole series of basic theoretical questions and strive to make breakthroughs in microcomputer technology development instead of following along behind the developed nations.

V. Prospects for Power Grid Protection Work in NARI

NARI is a Ministry of Energy Resources (Ministry of Water Resources and Electric Power) R&D base area for power grid protection technology and advanced equipment. During the process of relay protection technology development in China over the 15 years since the institute was founded, we have made our own contributions.

According to instructions from the State Science and Technology Commission concerning reform in the scientific research system, institute leaders proposed a shift from simple scientific research to an administrative body for scientific research, production, and technology in an effort to make greater contributions to the state and the electric power industry. Our participation in the international competition for the Tianshengqiao project in 1988 was a decisive step in this area.

To meet the need for a gradual discarding of rectifier and crystal tube protection in China's power grids, besides accelerating the completion of product sets, systemization, modularization, standardization, and typical design and extension work, we are now adopting concrete steps toward technology transfers or joint production and product dissemination at fixed-site plants in and outside of the Ministry of Energy Resources. We have now established technology transfer and cooperation agreements with relevant manufacturing plants in Acheng, Shanghai, Nanjing, Beijing, Baoding, Anhui, and Jiangxi. We also are actively exploring new routes for implementing horizontal integration in domestic and foreign competition to provide more and better high technology equipment to the electric power industry as quickly as possible.

Foreign Funds Help Develop Power Industry

40100070 Beijing XINHUA in English 0138 GMT 7 Sep 89

[Text] Beijing, September 7 (XINHUA)—The Huaneng International Power Development Corporation is using foreign funds to speed up the development of the power industry in electricity-short China, CHINA DAILY reported today.

Yu Minji, general manager of the corporation, said that negotiations are under way with foreign businessmen to import a 100,000-kilowatt gas turbine for a power plant in Shenzhen, China's first special economic zone.

The equipment will ease a severe shortage of electricity in Shenzhen that has forced factories to limit their operations to four days a week.

The corporation is negotiating with John Brown Engineering of Britain for the turbine and is expected to enter into negotiations with Foster Wheeler of Spain and Fiat of Italy for other equipment needed for the project.

John Brown is consortium leader for equipment supply of the Jiangbei Power Plant in Chongqing, Sichuan Province.

According to the general manager, the corporation is cooperating with the Shenzhen City Government on a larger power project, still under review, which will involve installing two 350,000-kilowatt generators. Further cooperation with the West will be sought on this project.

Meanwhile, the corporation will also start several other power projects around the country within the next couple of years.

These involve the Shantou power plant in Guangdong Province, the Yingkou power plant in Liaoning Province, the Shijiazhuang power plant expansion project in Hebei Province and the Beijing Gaobeidian power plant.

All will be equipped with two 300,000-kilowatt generators. Some will use Soviet equipment acquired in barter trade.

At the same time, the corporation is exploring with foreign companies a new way to develop the power industry in China—the so-called hard currency earning power development method.

This involves setting up a high hard currency earning factory, such as a ferrosilicon plant, in conjunction with the building of a power plant. Such a factory would consume about one-tenth of the plant's total electricity output. Ferrosilicon would then be sold abroad and the hard currency earned would be used to repay the power plant debts.

The general manager added that the corporation is studying the possibility of the new method with Spanish companies.

Second Unit of Lubuge Operational

40100072b Beijing XINHUA in English 1609 GMT 24 Sep 89

[Text] Kunming, September 24 (XINHUA)—The second generating unit of the Lubuge Hydroelectric Power Station in southwest China has recently been put into operation.

The power station, on the Huangni He between Yunnan and Guizhou provinces, is designed to have four 150,000-kW generating units with a total capacity of 600,000 kW.

The World Bank provided part of the funds needed in the construction of this power project.

Its first generating unit went into operation in late 1988.

The other two generating units were scheduled to go into production next year.

Modern Shafts Go Into Operation in Jilin

40130131a Changchun Jilin Provincial Service in Mandarin 2100 GMT 30 Aug 89

[Summary] A pair of modern medium-sized coal shafts with an annual production capacity of 750,000 tons, which is one of the province's key construction projects during the Seventh 5-Year Plan period, was completed and formally went into operation at the (Yucheng) coal mine of Shulan Coal Mining Administration on 30 August.

Large Coal Mine Planned for Ningxia

40100069a Beijing XINHUA in English 0803 GMT 5 Sep 89

[Text] Yinchuan, September 5 (XINHUA)—Preparations are under way for the development of a large coal mine in the eastern Ningxia Hui Autonomous Region, with coal reserves totalling 27.3 billion tons.

Covering 2,400 sq km, the field's reserve is equivalent to the total of Liaoning, Jilin, and Heilongjiang provinces in northeast China.

According to Liu Shanquan, chief engineer of the regional Bureau of the Coal Industry, the state will first develop a modern mine at Lingwu, about 40 km from the regional capital of Yinchuan and provided with convenient transportation facilities and abundant water resources.

The mine, scheduled to cover 198 sq km and with a verified reserve of 2.839 billion tons, will turn out 5.4 million tons a year upon completion in the 1991-95 period.

Coal reserves in Ningxia rank fifth in the country.

Mechanization Increases Coal Production in Shanxi

40100071a Beijing XINHUA in English 1513 GMT 21 Sep 89

[Text] Taiyuan, September 21 (XINHUA)—Shanxi Province, the leading coal producer in China, has mechanized its coal production by making use of foreign investment and importing advanced equipment over the past decade.

The province boasts 34 mechanized mines and 80 mechanized mining teams. Machines do 87 percent of the pit work at state mines.

Six major mining administrative bureaus have imported 4,500 sets of advanced coal mining equipment valued at 765 million yuan.

With modern equipment, a 100-member mining team of the Jincheng Mining Administrative Bureau produced 1.8 million tons of coal a year, setting a world record.

The introduction of advanced equipment, technology and management has made it possible to reduce the number of laborers while increasing output, said a mining official.

The total number of miners in the province was reduced by more than 10,000 over the past couple of years, yet its coal output jumped from 90 million tons in 1978 to last year's 246 million tons, the official said.

The local government has invested 4.7 billion U.S. dollars to import equipment and technology to build the Antaibao Opencut Coal Mine, considered the largest of its kind in Asia, and three other coal mines. The combined annual production capacity of these mines totals 43.3 million tons. Local economists anticipate that the investment will be recouped in seven years.

Shanxi Province, with coal reserves of 871 billion tons, accounts for one-quarter of the total coal reserves in the country. A national survey in 1988 showed 39 percent of the land in Shanxi covers coal resources.

One-quarter of China's total coal output and one-third of the country's coal exports come from Shanxi. Last year, the province turned over 175 million tons of coal to the state.

Wang Senhao, governor of Shanxi, said recently that his province welcomes more foreign investment. Compared with other parts of the country, Wang said, less investment will get better economic results in Shanxi because coal resources here are high quality, shallow and easy to exploit.

To ship more local coal to other provinces, Shanxi Province has invested a total of 4.5 billion yuan over the past decade in highway and railway construction. By the end of 1988, 11 of the 13 newly built trans-regional highways had gone into operation. They have the capacity to ship 23 million tons of coal annually.

A railway transportation network linking 400 feeder lines and 200 coal storage centers is now taking shape in the province. The network already handles 400,000 tons of coal a day.

Shandong Mining Update

40130134a Jinan Shandong Provincial Service in Mandarin 2200 GMT 15 Sep 89

[Summary] At present, Shandong Province is capable of excavating 107 tons of coal from the earth per minute, as opposed to 3 tons, 40 years ago. In 1949, the total coal output of the province was 1.78 million tons; while 40 years later, the total annual coal output has reached 55.59 million tons. At present, there are 7 coal mining administrative bureaus, 54 state-run coal mines, and 500 local-run coal mines in the province. Over the past 40 years, the province invested 6.8 billion yuan in coal industrial capital construction, and built 86 pairs of coal pits, and 17 coal washeries.

Oil, Gas Output Figures to August Released

40100071b Beijing CEI Database in English 18 Sep 89

[Text] Beijing (CEI)—Following is a table of the output of China's main oil and gas fields in the first eight months of this year, released by the China Oil and Gas Exploration and Development Corporation:

Name	Oil (10,000 tons)	Percentage of annual quota	Gas (100 million c.m.)	Percentage of annual quota
Daqing	3701.2	66.8	14.85	67.5
Shengli	2186.4	63.4	9.99	68.9
Liaohe	861.1	64.7	11.16	65.6
Zhongyuan	457.0	61.6	9.78	78.3
Xinjiang	423.1	65.1	3.30	—
Huabei	358.6	65.8	1.37	59.7
Dagang	264.3	61.5	2.49	69.2
Jilin	227.1	70.3	0.67	—
Henan	171.0	67.1	0.36	—
Changqing	94.7	69.1	0.15	—
Jianghan	62.3	65.6	0.42	—
Jiangsu	51.4	73.4	0.23	—
Qinghai	47.4	67.7	0.25	—
Yumen	35.9	79.8	0.09	—
Sichuan	8.8	87.6	41.56	69.3
CNOOC	61.8	68.7	—	—

Note: CNOOC—China National Offshore Oil Corporation

Structural Migration of East China's Oil and Gas Basins

40130074 Beijing ZHONGGUO KEXUE [SCIENTIA SINICA] in Chinese No 12, Dec 88 pp 1314-1322

[Article by Wang Tonghe [3769 0681 0735] of the Zhuozhou Geophysical Prospecting Bureau, Ministry of Petroleum Industry: "Structural Migration in Petroliferous Basins of East China"; revised manuscript received 17 Apr 87]

[Text]

Abstract

This article uses actual data from geology, geophysics, drilling, and other areas to provide a comprehensive description of structural migration in various types of basins, their oil generation periods, and laws of temporal and spatial distribution of oil and gas. It concludes with a preliminary discussion of the effects of subduction of the Pacific Plate toward the Asian continent on structural migration in the basins of east China, and shows that deep geological forces are the motive source of shallow strata structural migration in the basins.

Key words: structural migration, petroliferous basin, motive source

Structural migration is extremely common during the process of petroliferous basin development and evolution. It involves structural deformation, magmatic activity, sedimentation, the oil generation process, oil and gas migration and accumulation mechanisms, and so on of a basin in a specific geodynamic environment according to variational regularities along a specific direction. Structural migration is very important in evaluating the oil and gas prospects of new areas, forecasting the sequence of oil and gas pools, enhancing our understanding of old areas, opening up new realms, new categories, and new depths for oil and gas, and exploring the geodynamics and other basic questions of oil and gas provinces. This article uses the concept of structural migration for a rational interpretation of the temporal and spatial distribution of oil and gas provinces in the basins of east China, including marine areas. It concludes by considering the effects of rhythmic subduction of the Pacific Ocean plate toward the Asian continent in varying manners during different periods, intermittent creep-spread and slippage of the continental crust toward the ocean, and non-homogeneous stretching and thinning on structural migration in basins of the region.

I. Formation and Evolution of East China's Basins

After the Mesozoic, the stable platform of eastern paleo-Asia which had already combined and was sandwiched between the paleo-Pacific Ocean and paleo-Tethys collision zone underwent different structural activity than previously. As the extension ridge of the new Kula-Pacific Ocean plate created by lengthening of the Pacific Ocean Plate was compressed and sheared to the NNE, the continental crust of east China gradually became active and then disintegrated. There was widespread fracturing associated with the absolute dominance of compression or compressive shear in a NNE direction and the appearance of more intense magmatic activity eventually destroyed the long-term potential state of north-south compression.[1,2] Overall, along a boundary from Taixing Shan to Wuling Shan, there was large area subsidence during the Triassic and middle Jurassic in the west on a background of eastern uplifting and western downwarp which formed large subsidence basins typified by the Ordos and Sichuan Basins, while small fault-subsidence basins formed parallel to compression stresses in the east. Andean-type collision at the east and southeast margins of paleo-Asia in the late Jurassic and early Cenozoic[3] changed the potential state of eastern uplifting and western subsidence. The Ordos and Sichuan Basins in the west were gradually uplifted and shrank. However, on a background of general uplifting, fault blocks in the east underwent widespread fracturing and subsidence due to intense tension. Songliao Basin in northeast China is a typical late Cenozoic basin of this period. Erosion and planation during the late Cretaceous and Paleocene brought new structural features to northeast China and other areas and regional fracturing-subsidence universally intensified. Bohai Bay, Nanyang,

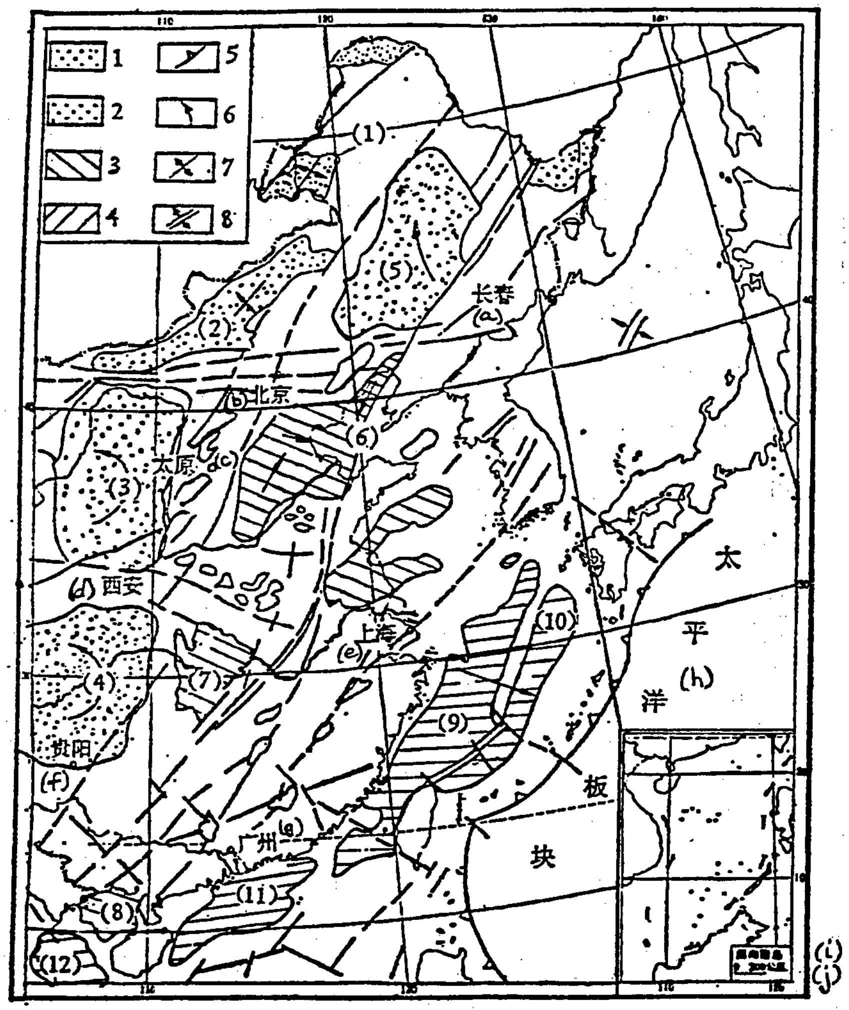

Figure 1. Distribution of Petroliferous Basins in East China

Key: (1) Hailar Basin (2) Erlian Basin (3) Ordos Basin (4) Sichuan Basin (5) Songliao Basin (6) Bohai Bay Basin (7) Jianghan Basin (8) Beibu Gulf Basin (9) East China Sea Continental Basin (10) East China Sea Frontal Edge Basin (11) Zhujiangkou [Pearl River Mouth] Basin (12) Yingge Hai Basin 1. Intra-plate subsidence basin 2. Intra-plate fault-subsidence basin 3. Intra-plate fault-subsidence basin 4. Plate margin basin 5. Subduction zone 6. Direction of sedimentation center migration 7. Bidirectional structural migration 8. Tension fracture structural zone. (a) Changchun (b) Beijing (c) Taiyuan (d) Xi'an (e) Shanghai (f) Guiyang (g) Guangzhou (h) Pacific Ocean plate (i) Islands of the South China Sea (j) Kilometers

Biyang, and Jianghan Basins, Subei Basin further to the east, and others usually tracked or accommodated mainly to fractures with a NE or NNE direction or formed an echelon with associated fracturing in a NW and WNW direction. The former are often severed by the latter or alternate with uplifts which together surround the many large fault-subsidence basins which developed. In the late Tertiary, the Indian plate collided with the Eurasian continental crust[4] and a large area of west China was uplifted. Compressive stresses on the western margins of the Ordos and Sichuan Basins intensified. In the east, the effects of the eastward shift of the Pacific Ocean plate subduction zone changed Bohai Bay, Jianghan, Subei, and other fault-subsidence basins into subsidence basins. On the other hand, the East China Sea, South China Sea, and other basins at the continental margin subsided quickly and gradually formed new channel, arc, and trough systems[4] at the eastern edge of the basins. Overall, the occurrence, development, and formation of east China's basins exhibit regular gradations of sequential evolution from west to east, with a shift from old to new in period and from strong to weak in strength. This indicates that the basins subsided in a stepped fashion while areas of sedimentation moved successively eastward. Their temporal and spatial distribution are shown in Figure 1.

The most interesting fact is that the spatial distribution of oil and gas is basically identical to the fault-block

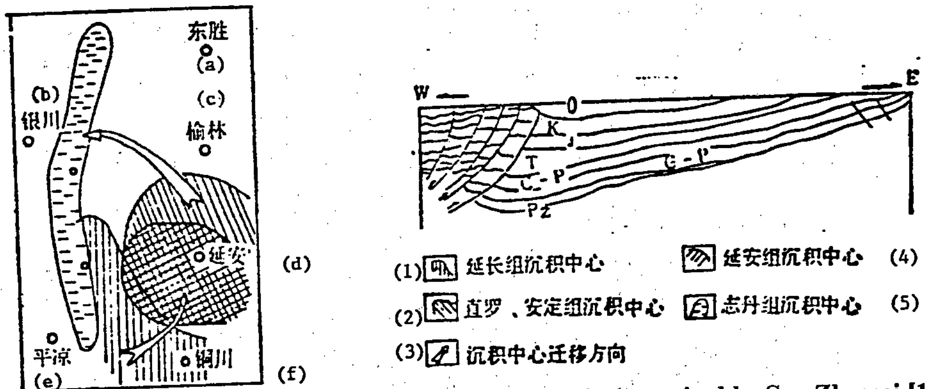

Figure 2. Migration of Mesozoic Sedimentation Center in Ordos Basin (as revised by Sun Zhaocai [1327 5128 2088]) (left: plain view chart; right: cross section)

Key: (a) Shulin (b) Yinchuan (c) Yulin (d) Yan'an (e) Pingliang (f) Tongchuan (1) Yanchang group sedimentation center (2) Zhiluo and Anding group sedimentation center (3) Direction of sedimentation center migration (4) Yan'an group sedimentation center (5) Zhidan group sedimentation center

basins which have continued to subside since the Cenozoic. This is particularly true of the structural and sedimentary categories of the basins and their evolutionary mechanisms, which determine the types of basin oil and gas pools and the extent of rich oil and gas accumulation, and reflect the oil formation characteristics of oil and gas provinces in east China. It should be noted in particular that as the oil generation centers migrated, there was always a corresponding sequence of oil and gas pools in a girdle or semi-girdle distribution around them, indicating that the oil and gas moved over short distances and accumulated locally. There are many similar reports in the literature.[5,6] The objective facts give us a profound understanding that structural migration in the basins of east China and sequential migration of oil generation centers and oil and gas pools which they controlled are characterized by extremely common regularities.

II. Characteristics of Structural Migration in the Petroliferous Basins of East China

East China's basins can be differentiated according to early and late development and withering. With different basement qualities, stress-bearing states, and changes in boundary conditions, the basins gradually formed various independent sedimentation systems and structural categories. Thus, each had its own particular structural migration characteristics.

A. Characteristics of Structural Migration in Large Subsidence Basins

Most of these basins formed on rigid basement fault blocks. Their basement was not damaged during their formational period and they are characterized mainly by tilting of integral basement fault blocks. Thus, there was obvious structural migration of sedimentation centers during the process of basin development and evolution. During the early period of basin development, for example, the Ordos Basin was affected by Indosinian movement.[7] The area of upper Triassic system Yanchang group inland facies sediments extended with a WNW strike and the uncompensated sedimentation and subsidence centers were located on the southwest side of the basin (Figure 2). The northeast flanks of the asymmetrical basins were extremely broad and gentle, while the southeast flanks were rather steep and narrow, making the sedimentary bodies wedge-shaped. The basin was uplifted temporarily and eroded from the late Triassic to the initial part of the early Jurassic, creating a paleomorphology that was high in the west and low in the east, and high in the north and low in the south. Next, compressive stress in an east-west direction intensified and caused intensive uplifting in the east and reverse faulting and folding of the western margin. The result was an obvious northward movement of the water body and migration of the Yan'an group lake facies sedimentation center to near Yan'an. The upward basement slope from east to west in the previous era continued and the water body expanded and moved north. The Zhiluo and Anding group sedimentation centers and their lithofacies zones extended along a north-south orientation. The maximum total sediment thickness at the western side of the basin was as much as 3,000 m and they had the properties of compensated sediments. The early Cretaceous was the final period in the basin sedimentation cycle and was manifested by gradual shrinkage of the scope of sedimentation and overall regression of lake water toward the west. The sedimentation center migrated to a line running north-south from Tianchi to Huanxian, ending the developmental history of the large subsidence basin.

It is apparent that the regular tilting movement of the basement fault blocks in the Ordos Basin controlled a counter-clockwise rotation of the basin sedimentation centers. Particularly interesting is that the sedimentation center in Sichuan Basin show similar migration

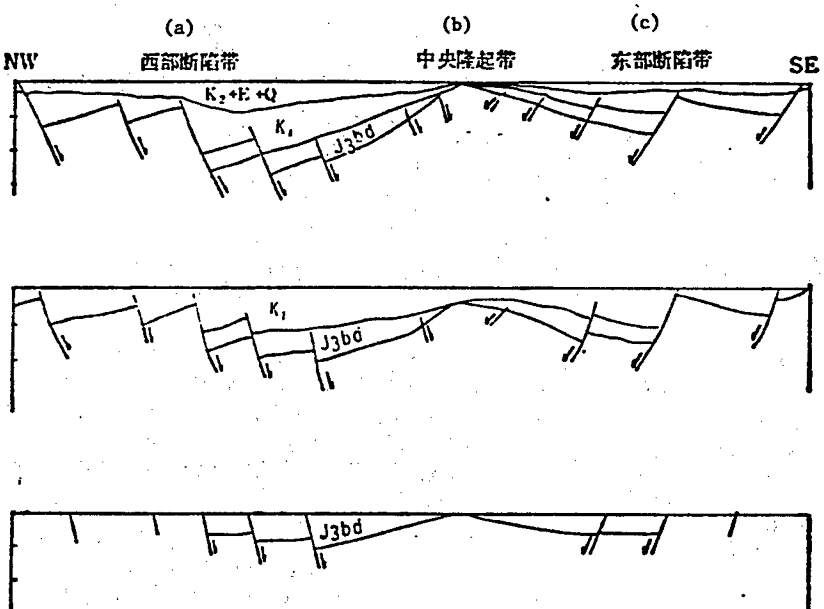

Figure 3. Cross-Sectional Diagram of Structural Migration in Erlian Basin
Key: (a) Western fault-subsidence zone (b) Central uplift zone (c) Eastern fault-subsidence zone

characteristics.[8] This provides clues and foundations for studying crust tilting activity over a large region (Figure 1).

B. Structural Migration in Basins With Two Depressions Separated by an Uplift

These basins developed mainly on the Variscan folding zone basement. The basement was relatively young, so it was not very rigid. Thus, the grabens are long and narrow, small and deep. The basin's structural characteristics are a group of reverse-dip paired step-shaped fault blocks which slipped in the same direction to form a structural configuration of two depressions with an uplift between them. The structural migration characteristics of this type of basin will be described here using the Erlian Basin as an example.

Erlian Basin developed on a background of late Jurassic large-scale magmatic eruption. The crust was preheated, loosened, and weakened. Afterwards, it cooled and became brittle, the tensile strength declined, and there was widespread fault block tension fracturing and subsidence. During the early period of basin development, its tensile stress was created by a rise in the geomorphological load equilibrium in the associated thermal dome-shaped uplift region. Thus, it was easiest for the sites of maximum curvature of the two flanks along the ridge of the uplift to be pulled apart, and afterwards gravity-induced horizontal subsidence destroyed the original gravitational equilibrium and forced a new gravitational readjustment. Then, the nearby fault blocks also gradually separated and formed new fractures or fault-subsidences. Thus, fractures on both sides near the central uplift zone formed earlier, were active for longer periods, have greater displacements, and dissect the basement deeply. Away from there, fracturing activity becomes later in sequence, the time period shortens, and the fault displacement is smaller. Thus, sedimentation centers of fault-subsidences which subsided evenly under control by a group of graded regular fractures must have obvious migrational regularities. Therefore, fault-subsidences on both sides near the central uplift zone formed earlier and have a larger scale and thicker sediments. Away from there, the fault-subsidences developed later in sequence, the scale gradually grew smaller, and there was a corresponding thinning of the sediments (Figure 3).

From the perspective of petroleum geology, the overlapping strata and thickening of the fault-subsidences along two sides near the central uplift zone were conducive to hydrocarbon conversion and preservation and the many traps in the synsedimentary structures were conducive to rich accumulation of oil and gas. This interpretation was confirmed by practice in petroleum exploration.[9] Hailar Basin, located in the same structural element but with a lower degree of exploration, also has a similar structural configuration and structural migration regularities and should receive attention during petroleum exploration.

What should be noted here is that since the late Cretaceous, uplifting of Daxing'anling on the eastern side of the basin caused lifting and tilting activity in the fault blocks east of the uplift zone, while tilting effects on the fault blocks to the west became stronger, causing the sedimentation center of the basin during the subsidence period to move from east to west. Thus, the fault-subsidence zone in the west is even more conducive to oil and gas generation and preservation.[11]

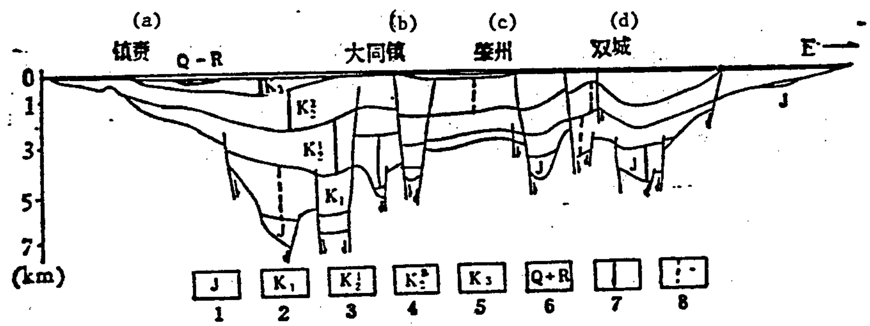

Figure 4. Horizontal Cross-Sectional Diagram of Sedimentation Center Migration for Various Structural Strata in Songliao Basin (according to Cheng Xueru [4453 1331 0320])

Key: 1. Jurassic structural strata 2. Lower Cretaceous structural strata 3. Middle Cretaceous upper structural strata 4. Middle Cretaceous lower structural strata 5. Upper Cretaceous structural strata 6. Cenozoic structural strata 7. Primary subsidence axis 8. Secondary subsidence axis (a) Zhenlai (b) Datongzhen (c) Zhaozhou (d) Shuangcheng

C. Structural Migration Characteristics of Large Fault-Subsidence Basins

Songliao Basin is representative of this type of basin. It is a typical fault-subsidence basin which developed gradually after the late Mesozoic. It was subjected to the effects of a high ground temperature field during the Triassic which caused curvature and uplifting of the crust and erosion, so there is a universal absence of sediments from that period. During the Jurassic, fracturing fracture-subsidence activity gradually strengthened and formed a horst/graben system extending in a NNE direction. During the middle period of fault-subsidence, there was intense fracturing activity in the Mingshui-Gudian fracture zone and Lamadian fracture and the thickness differential in the two strata of the fault is as great as 2,000 to 3,000 m, indicating a rapid rate of graben sedimentation during the subsidence period (296 m/a), great thickness, and so on. During the initial part of the early Cretaceous, the crust gradually cooled and its elasticity was restored. The basin subsided evenly, gradually eliminating the eastern sedimentation center during the fault-subsidence period, and it entered the downwarp development stage rather early. However, the western part was still in a fault-subsidence or fault-downwarp transition stage. Afterwards, fracturing activity in the basin weakened and overall it changed to a subsidence development stage manifested by subsidence over a large area. Overall, the scope of sedimentation in the eastern part of the basin shrank and became gradually thinner. The scope of sedimentation in the western part continued to expand and the thickness increased. There was an obvious trend of a gradual migration of the basin sedimentation center from east to west (Figure 4). The basin was uplifted in the late Cretaceous. The lake basin shrank, was reduced in area, and the sediments became thinner. During this time, the lake basin sedimentation center also migrated about 30-plus km to the west. The east (south) of the basin was abruptly uplifted after the Cenozoic while the west also accumulated 300 to 400 m of loose sediments, indicating continued westward migration of the basin's sedimentation center.[12] It should be pointed out that the basin's change in shape and migrating sedimentation center, particularly the Daqing placanticline formed by westward migration of the oil generating center, created an extremely favorable geological background for forming especially large oil pools.

D. Structural Migration Characteristics of the Bohai Bay Basin

Bohai Bay Basin is a rift basin which developed after the Mesozoic and Cenozoic. Yanshan activity during the late Cretaceous uplifted the entire region. After undergoing erosion and leveling during the Paleocene, Eocene rift valley activity intensified and a series of grabens and semi-grabens with mainly compensation sediments along the NE and NNE-oriented fractures developed next. There were obvious phases and regularities in their occurrence, development, and withering. Overall, as time passed, the fracturing activity and its synsediments became newer in sequence moving from west to east, and there also was gradual evolution in fault-subsidence shrinkage and disappearance moving from west to east. In the fault-subsidence zone in the western part of Jizhong Depression, for example, the Eocene to Oligocene Sha 4 member ($EK\text{-}Es_4$) period was mainly a subsidence region whereas fault-subsidence in the eastern part became a primarily subsidence zone only during the Oligocene Sha 3 to Sha 2 member (Es_{2+3}) period. By this time, the former had already withered, changed shape, and was uplifted (Figure 5, top). While the fault subsidence zone in west Huanghua Depression was in a stage of mainly subsidence from the Oligocene Sha 3 to Sha 1 members, the fault-subsidence zone in the eastern part of the Jizhong Depression gradually withered. During the Oligocene Sha 1 to Dongying member period, the fault-subsidence zone in east Huanghua Depression subsided quickly, while the fault-subsidence zone in its western part gradually shrank and changed shape. By the late Oligocene, the subsidence region in the

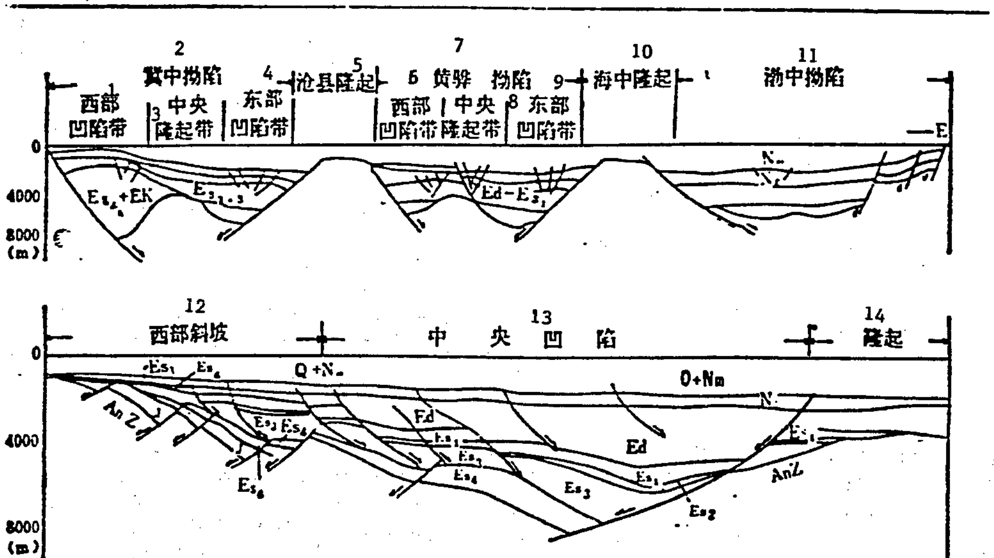

Figure 5. Horizontal Cross-Sectional Diagram of Structural Migration in the Bohai Bay Basin (top) and Lower Liao He Rift Valley (bottom)

Key: 1. Western depression zone 2. Jizhong depression 3. Central uplift zone 4. Eastern depression zone 5. Cangxian uplift 6. Western depression zone 7. Huanghua depression 8. Central uplift zone 9. Eastern depression zone 10. Haizhong (mid-sea) uplift 11. Bozhong depression 12. Western slope 13. Central depression 14. Uplift

basin had migrated from the west to Bozhong Depression. This sequential creation of fault-subsidence zones moving from west to east, gradual changes in synsediments, change in shape and enclosure of the fault-subsidence zone, and gradational regularities in sequential migration from west to east also determined that the constitution of the basin's generating, reservoir, and capping strata would have variational regularities in types of oil and gas pools.[13] These structural migration regularities are even more apparent in the lower Liao He rift valley. During the initial period of rift valley expansion during the Mesozoic, the NE-striking and NW-dipping faults controlled fault block tilting to the west. Moreover, intense expansion of the rift valley from the Sha 3 to late Sha 1 changed the direction of tilt of the fault blocks and tilt slippage and rotation of the fault blocks gradually strengthened moving from west to east, resulting in obvious eastward migration of the sedimentation and oil generation centers during the rift valley period (Figure 5, bottom). In the late Oligocene, weakened tensile stresses created NE-oriented reverse faults and stepped normal faults conjugated with them and tilted to the southwest. This changed the limited fault-subsidence sediments to large area depression sediments and formed a dual-layer structure with a vertical sequence in the rift valley basin, and the depression sediments thickened in sequence moving from north to south. At the same time, accumulating sediments in Jiyang Depression also overlapped moving south to north to develop a late Cenozoic depression basin centered on Bohai Sea.[6]

E. Structural Migration Characteristics of Marine Basins

Most subsidence zones in the marine basins formed a row of fracture zones in a mainly NNE direction with an alternating positive and negative sequence, certain spacing properties, and obvious migration toward the ocean. The East China Sea Basin will now be used as an example to explain structural migration in the marine basins. These basins had different structures, formational mechanisms, and evolutionary histories in strata and structures. The sequence moving west to east is a continental shelf basin, continental shelf frontal edge basin, and sea trench basin (Figures 1 and 6). Subduction of the Pacific Ocean plate toward the Eurasian continent and the continual creep-spread, slippage, and accretion strengthened fracturing activity and sedimentation was in newer positions in the East China Sea Basin in sequence from west to east, so the migrational regularity is movement toward the ocean. The main development periods for these three basins were, respectively, the late Cretaceous to Miocene, middle and late Miocene to Pliocene, and Quaternary. This resulted in asymmetrical fault-subsidence with eastern faulting and western overlap. Each developed later, subsided more, and had thicker sediments than the previous one moving from west to east, indicating substantial eastward progression of the scope of the basins during the middle and late Miocene. However, more intense subduction of the Pacific Ocean plate to the west after the late Miocene caused intense back-arc expansion and then emergence of the continental frontal edge basin. From the late Miocene to early Pliocene, the fault-subsidences expanded horizontally and vertical deep subsidence gradually intensified. This expansion and pressure stress created on the east and west sides caused intense deformation and folding of the continental shelf in the distant subduction zone and even the appearance of reverse

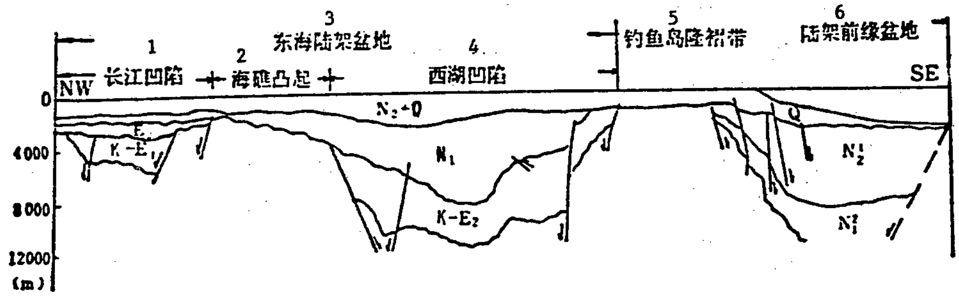

Figure 6. Horizontal Cross-Sectional Diagram of Structural Migration in the East China Sea Basin (according to the Ministry of Geology and Mineral Resources)

Key: 1. Chang Jiang depression 2. Reef prominence 3. East China Sea continental shelf basin 4. Xihu depression 5. Diaoyu Island uplift-folded zone 6. Continental shelf frontal edge basin

thrust faults. This caused the middle and late Miocene sedimentation center to migrate west, the opposite direction to the main direction of migration. In the transition from normal to reverse faults on the east side of Xihu Depression, for example, the strata folded to form the Zhedong [east Zhejiang] placanticline.

In the fault-subsidence period of the basins, slopes formed on one side of the fractures. The large fault displacement, rapid subsidence, and thick sediments filled them quickly with sediments rich in organic matter. Later, horizontal compression activity created anticline structures or placanticlines which became sites of rich oil and gas accumulation. This was confirmed by wells with industrial oil and gas flows.[14]

The formation, development, and expansion of the Yingge Hai and South China Sea Basins also have migrational regularities toward the ocean. The horizontal sequence of the structural categories overall reflects the evolutionary sequence of the basins. Over time, regions of intense expansion and aggradation in marine transgression positions had gradational regularities of migration toward the ocean.[14]

III. The Relationship Between Structural Migration and Oil and Gas

Structural migration is, of course, closely related to Mesozoic basin formation and evolution, and oil and gas provinces are extremely common in east China. Thus, analysis of control of the distribution of sedimentary structures by structural changes and characteristics of lithofacies zones, and in particular consideration of the movement and accumulation of petroleum and natural gas, has its own special significance.

From the viewpoint of oil and gas exploration, whether within stable platforms or at active continental margins, structural migration controls the directional development and evolution of a region or large basin. Generally speaking, as a basin develops from early uncompensated sedimentation to compensated sedimentation and expansion during the middle period, later supercompensated sedimentation, and on up to basin withering, the sediment expansion or stable sedimentation periods are most conducive to oil and gas generation. The middle period of structural deformation caused by intense stress activity is the period of greatest oil and gas migration and accumulation. Thus, the various types of structural traps formed during the middle and late periods played important roles in controlling oil and gas accumulation. In Songliao Basin's Daqing placanticline and East China Sea's Zhedong placanticline, for example, the formation of huge oil pools is not accidental, especially in the former.

In a large fault-subsidence basin, structural migration often results in basement fault block subsidence to form a stepped configuration along a certain direction. Thus, generating, reservoir, and capping strata and their compositional pattern must migrate along the same direction, and the sequence of corresponding oil and gas pools varies. This is especially true in a basin with obvious structural migration, where oil and gas pools have zonal characteristics. In Bohai Bay Basin, and especially in Jizhong Depression where fractures developed early and cut deep into the basement, the oil generating rock is in direct contact with the basic rock. This is extremely conducive to formation of ancient buried hill composite oil and gas pools generated above and reservoired below. In Renqiu Depression, for example, large ancient buried hill oil and gas pools account for most of its reserves. In Huanghua Depression on the east side of Jizhong Depression, however, the primary positions are occupied mostly by synsedimentary structures like reverse drag anticlines, synsedimentary, fault anticlines and other oil and gas pools. Further east to the Bozhong and Jiyang Depressions, older fracturing activity and newer oil generating rock systems formed a generation below and reservoiring above type, and draped anticlines, strata thinouts, and other oil and gas pools predominate. It is apparent from all of the above that moving west to east, the oil and gas pool types go from generation above and reservoiring below to self-generating and self-reservoiring, and to generation below and reservoiring above, giving them an obvious zonal quality in planar distribution. This has theoretical significance as well as real value.

In the Liaohe Rift Valley region, the type and distribution of oil and gas pools were obviously controlled by basement fractures and contemporaneous fractures. On the west slope, for example, buried hill, overlap, and lithic thinout oil and gas pools developed. In deep subsidences, there are reverse drag, mudhill penetration, draped anticline and other synsedimentary structural oil and gas pools. The eastern slope zone, however, mostly developed fault nose structure and reverse thrust fault anticline oil and gas pools which have an obvious zonal quality in their planar distribution.

In large subsidence basins, the absence of fracturing of basement fault blocks meant that there was no obvious differential activity within a short distance. Thus, the capping strata are structurally simple and their structural migration is manifested only as migration of sedimentation centers. Moreover, most of these basins developed over long periods and have many stages of oil formation periods, migration periods, and accumulation periods, so the relationships among their generating, reservoir, and capping configurations are rather complex. The Ordos and Sichuan Basins are typical examples. Thus, from the perspective of structural migration, particularly migration of sedimentation centers, regularities in temporal and spatial distribution are especially important when searching for their oil and gas pools.

In summary, it is not hard to see that structural migration controls generating, reservoir, and capping strata in petroliferous basins as well as their compositional pattern, particularly the distributional characteristics of oil and gas pool categories. Thus, when surveying and prospecting, we first should clarify the number and types of structural strata in basins and their temporal and spatial composition pattern. These are then combined with other petroleum geology conditions to explore distributional relationships between structural migration and oil and gas pool types to enable formulation of the corresponding exploration procedures and methods. This can provide very good results.

IV. Exploring the Motive Force Mechanisms of Structural Migration

There is an obvious interrelationship between structural migration and the temporal and spatial distribution of oil and gas in petroliferous areas of east China. Still, the motive force mechanisms behind structural migration are a topic which deserves additional discussion. From the perspective of plate tectonics, expansion of the Indosinian paleo-Tethys Sea caused thrust compression in a NE direction and sealed off the residual Qinling-Huaiyin and You Jiang sea trenches, which in turn formed a large subsidence basin alone one side of the folded zone. Around the early Jurassic, the new Kula-Pacific Ocean plate created by lengthening of the Pacific Ocean plate expanded and moved to the NNW.[10] Profound changes occurred in the structural configuration of east China and changed the original WNW orientation of large depressions and uplifts to a NE-NNE distribution. In the late Jurassic to early Cretaceous, the Pacific Ocean plate was subducted toward the Asian continent and submerged. The resultant mantle convection currents gradually stretched and thinned the continental crust, and a series of fault-subsidence basins developed in east Inner Mongolia and northeast China. From the late Cretaceous to early Tertiary, the direction of subduction of the Pacific Ocean plate shifted from the original NNW to WNW.[13] Its effects also formed the Bohai Bay, Jianghan, Subei, and other basins. In the late Tertiary, collision of the Indian plate with the Eurasian continental crust and eastward movement of the zone of subduction of the Pacific Ocean plate caused continual creep-spread, slippage, and obduction of the east China continental crust, and the East China Sea, South China Sea, and other marine basins at the margin continued to develop. Analysis of the spatial distribution and development sequence of these basins, particularly data on volcanic activity, convection current values, crust thickness, and other areas,[10,16] shows that the evolutionary tendency of basins in east China was continual subduction of the oceanic crust and gradual aggradation of the continental crust. On this basis, it is felt that rhythmic subduction of the Pacific Ocean plate toward the Asian continent and uneven stretching and thinning of the continental crust are the primary motive forces for structural migration in the basins of east China.

Another important question which is very deserving of attention is how movement of deep material induces structural migration in shallow strata basins. The interpenetration of geology and geophysics in the past few years leads one to feel that fractures in deep strata of the crust are not connected with upward and downward motion of shallow strata fractures. Fractures in deep strata of the crust develop from deep areas during the process of upward arching of the upper crust, whereas fractures in shallow strata are formed during the process of lateral tension of the upper crust. All the strata between them are composed of alternating boundaries with different seismic wave velocities (high anomaly or low resistance strata). Moreover, each of the boundaries are structural slippage surfaces.[17] When the upper mantle arches upward or the magmatic diapire places the upper mantle in a tension state, horizontal shear flow spread occurs in intermediate strata composed of slippage surfaces and causes brittle cracking, slippage, or rotation. The uneven thickness, material properties, and so on of intermediate strata give different structural migration characteristics to shallow strata fault block basins (Figure 7). In Bohai Bay Basin, for example, there is a fracture system composed of several shovel-shaped normal faults, most of which are tilted in the direction of Pacific Plate subduction. When mantle convection created by plate subduction flows into the upper part of the

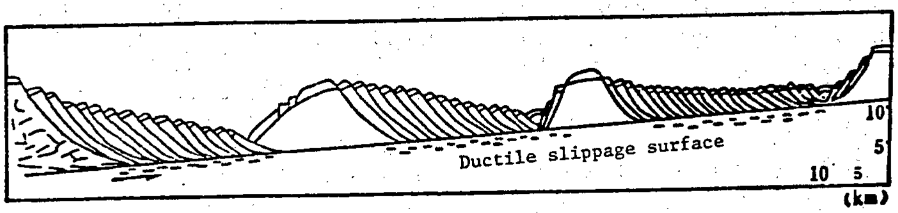

Figure 7. Cross-Sectional Diagram Illustrating Structural Migration in Petroliferous Basins

crust, horizontal shear flow spread occurs in the intermediate slippage surface and induces slippage and rotation of shallow strata fault blocks in a specific direction. Thus, there is a variational regularity of gradational slippage of the normal faults and the blocks between them. The sedimentary combination it controls, the type of structural traps, and the sequence of oil and gas pools change or migrate along with them. Thus, we feel that there is a relationship of mutual restriction between shallow strata and deep strata structures. Shallow strata structures and their activity play a role in inducing movement in the material of deep strata, whereas movement of deep strata material is the deep background which creates tension stress on shallow strata basins and is the source of motive power for basin structural migration.

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Liaohe Output Exceeds Plan

40130131b Shenyang Liaoning Provincial Service in Mandarin 0930 GMT 2 Sep 89

[Summary] By the end of August this year, the crude oil accumulated output of Liaohe oil field topped the figure of 100 million tons, and its natural gas output reached 2.35 million cubic meters. Liaohe was opened in March 1970. Over the past 20 years, it has opened 13 gas fields. Over the past 5 years, the yearly average increase in its crude oil output has reached 1 million tons, and the annual increase in oil deposits which have good prospects has reached more than 100 million tons. Its total crude oil output in 1986 reached more than 10 million tons, and has ranked the oil field third in the country. In 1988, it realized 12.58 million tons of crude oil and prefulfilled the Seventh 5-Year Plan by 2 years.

Xinjiang Well Achieves Highest National Yield

40100069b Beijing XINHUA in English 1418 GMT 7 Sep 89

[Text] Urumqi, September 7 (XINHUA)—The No. 193 Oil Well in Karamay in the Xinjiang Uygur Autonomous Region, has generated 3.78 million bbls of oil over the past 31 years, ranking first among oil wells across the country.

The oil well, which began production on September 3, 1958 with a daily production of 1,820 bbls, still generates 154 bbls a day.

In addition to oil, the well has also produced 73 million cubic meters of natural gas over the past 31 years.

Oil, Gas Resources Found Near Shenyang

40130134b Beijing ZHONGGUO XINWEN SHE in Chinese 0222 GMT 19 Sep 89

[Report: "Rich Oil and Gas Resources Discovered Around Shenyang"—ZHONGGUO XINWEN SHE headline]

[Text] Shenyang, 19 Sep (ZHONGGUO XINWEN SHE)—A prospecting department has discovered rich petroleum and natural gas resources around Shenyang, the largest industrial city in northeast China. At present, five oil fields have been built here with an annual capacity of some 3 million tons of crude oil and some 300 million cubic meters of natural gas. The area has become another important oil and gas production base of China.

According to the report of the petroleum prospecting department, the area of oil and gas reserves around Shenyang is approximately 200 square kilometers, and approximately 300 million tons of petroleum reserves and some 10 billion cubic meters of natural gas reserves have been initially ascertained.

In recent years, the oil industry has rapidly developed in the vicinity of Shenyang, the area of oil and gas reserves has been continuously enlarged, and the extraction and production of oil and gas has begun. Here, five oil fields, including Damintun, Fahaniu, Jingan, Niuju, and Ciyuzhaitong, have developed one after another; approximately 1,000 oil wells have been sunk, and two large oil production plants have been built with a daily output of approximately 10,000 tons of crude oil.

At present, oil and gas prospecting in the Shenyang area is continuing. A large number of oil and gas geological structures were also discovered this year so that the area of oil and gas reserves has been expanded again. Experts have held that the prospects for oil and gas development and building in the Shenyang area are very promising and this will bring good luck to industries in Shenyang whose energy resources are gradually in short supply.

Natural Gas Discovered Near Urumqi

40100072c Beijing XINHUA in English 1258 GMT 24 Sep 89

[Text] Urumqi, September 24 (XINHUA)—A natural gas well has just been drilled in the suburbs of Urumqi, capital of northwest China's Xinjiang Uygur Autonomous Region.

The well, 50 kilometers south of the city, produces 13,000 cubic meters of natural gas daily.

The drilling of the well has verified that the area has suitable geological conditions for the forming and gathering of oil and natural gas. The well shows a bright future for prospecting for oil and gas in the area, according to a local oil expert.

Sichuan Completes Inter-Province Gas Pipeline

40100071c Beijing XINHUA in English 1219 GMT 14 Sep 89

[Text] Chengdu, September 14 (XINHUA)—An inter-province natural gas pipeline was recently completed in Sichuan Province.

The pipeline is to supply at least 2 billion cubic meters of natural gas to 400 industrial enterprises and 1 million urban households in Sichuan, Yunnan, and Guizhou provinces.

Exploitation and utilization of natural gas has made giant strides since the founding of new China in 1949, especially over the past decade.

Local geologists have discovered 71 gas fields and 29 gas-bearing structures. Over 950 gas wells have so far been sunk in the province with a combined annual output of more than 5 billion cubic meters, nearly half of the total national figure.

Since a contract responsibility system was introduced in China's oil industry in 1984, gas output in Sichuan has increased at an annual rate of 2 percent. Last year output jumped to 5.94 billion cm.

After building a desulphurization plant with imported gas purifying equipment in 1980, the province was able to process 4 billion cubic meters of gas annually, surpassing the previous processing capacity by one-third.

Millions of urban residents in the province now use gas for cooking instead of wood.

Some Problems in Construction of Nuclear Power Plants

40130122 Beijing LIXUE YU SHIJIAN in Chinese Vol 11 No 3, Jun 89 pp 1-10

[Article by Sun Delun [1327 1795 4858] and Peng Ruhai [1756 1172 3189], Hengyang Institute of Engineering, Ministry of Nuclear Industry]

[Excerpts] Sun Delun, male, born in 1931, graduated from Qinghua University in 1955, served as deputy director of the Mechanics of Materials Laboratory at Shanghai Jiaotong University. He was transferred into the Ministry of Nuclear Industry (MNI) in the early 1960's, and served as deputy director of MNI's Southwest Institute of Structural Mechanics. In 1984, he became institute director and a professor at MNI's Hengyang Institute of Engineering. He has been on the board of directors of societies of mechanics in Shanghai, Sichuan Province and (currently) Hunan Province, and presides over the Hengyang Municipal Scientific Cooperation Group. For years he has been active in research in nuclear industrial technology and in teaching and research in solid-state mechanics. In addition, he has contributed to the development of China's nuclear weapons and to the construction of nuclear power [plants].

Abstract: Since China's work on nuclear power plant construction began, quite a few problems have arisen in various disciplines. An attempt is made here to comprehensively and systematically discuss the close relationship between nuclear power plant construction and structural mechanics. An analysis of some special mechanics problems in nuclear power plant construction is given, and some directions that future research should take are proposed.

1. Introduction

[Passage omitted] As a major nuclear nation in the world, China made a late start in nuclear power (except for the six reactors currently operating in Taiwan), but has made rapid progress in recent years. The safety shell of the Qinshan Nuclear Power Plant, designed and built by the Chinese, has been completed. The Daya Bay Nuclear Power Plant in Guangdong, a joint venture with foreign investments, has entered its peak construction period and is expected to supply electric power within 3 to 5 years.

A nuclear power plant consists of two parts: the nuclear island and the conventional island. The former involves a special environment of high temperatures, high pressure, and high radiation dosage; it requires extraordinary structural and system safety. Nuclear safety is of paramount importance; once an accident or radiation leakage occurs, it not only leads to gross economic losses, but may also endanger the safety of a vast area around the power plant and that of the area's residents. It can also bring political damages to the nation. The Three Mile Island accident in the United States in 1979 and the Chernobyl accident in the Soviet Union in 1986 are good examples. Since nuclear power requires rigorous structural safety, China's [State] Nuclear Safety Administration established a legal document[15] in 1986 which not only laid down conventional design requirements (e.g., temperature, pressure, and radiation), but also specified safety design criteria for low-probability occurrences such as a hurricane, an earthquake, an impact by aircraft or meteor, or a core melt-down. [passage omitted]

2. Mechanics Problems in Nuclear Power Construction

2.1 Material Performance Under Radioactive and Corrosive Environments

High-temperature boric-acid solution in the pressure boundary and chlorine ions in the steam generator are causes for chemical and stress corrosion. Chemical corrosion has been studied extensively, and specific guidelines are available for selecting corrosion-resistant materials for different types of reactors.[1] Chemical corrosion may be kept to a minimum by using austenitic stainless steel and eliminating the chlorine ions in the steam. Nickel-based alloys INOR-8 and PE-16 are even more corrosion resistant than austenitic stainless steel at high temperatures, and have also been recommended as structural materials outside the core. Not a great deal of research has been done on stress corrosion in reactors and it remains a problem awaiting quantitative solutions.

The radiation in a reactor is mainly due to neutrons. After 40 years of operation, a typical pressurized water reactor (PWR) would have about 3×10^{23} n/m^2 of fast-neutron injection onto the pressure-vessel inner wall at the center of the core.[1] This quantity is one order of magnitude smaller in a boiling water reactor (BWR). In a PWR, attention should be given to the effects of neutron radiation on the enclosure and the pressure vessel.

After irradiation, most metals would have an increased yield limit and strength, a decreased plasticity and toughness, and increased swelling and creep rates. It should be pointed out that, as the neutron dose increases, the brittle transition temperature of these metals would increase. Figures 4 and 5 show the relationship between the neutron injection flux and the performance standards of pressure-vessel steel, and the increase of the brittle transition temperature, respectively. At high neutron doses, the brittle transition temperature may reach or surpass the room temperature. Although the transition temperature is less than the normal operating temperature of the pressure vessel, the temperature may fall below the brittle transformation temperature when the reactor is shut down for replacing fuel rods or for other reasons while the pressure is still high. Under these conditions the pressure vessel can easily be damaged by brittle fracture.

Radiation makes the material more porous and increases the coefficient of expansion and the amount of creep. This can lead to burn damage and local collapse of

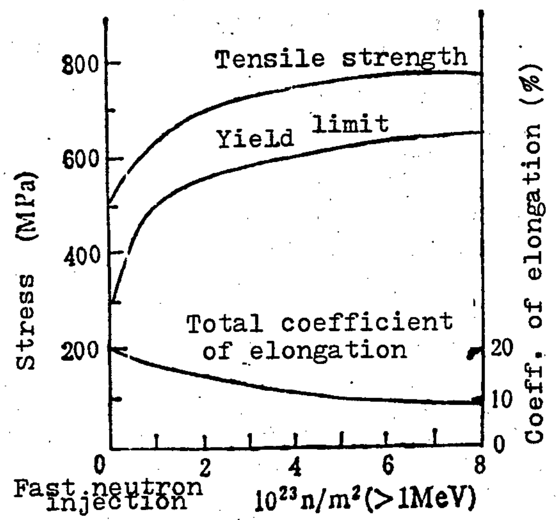

Figure 4. Effects of fast neutron radiation at 260°C on the strength and plasticity of ASTM A533-B pressure-vessel steel.

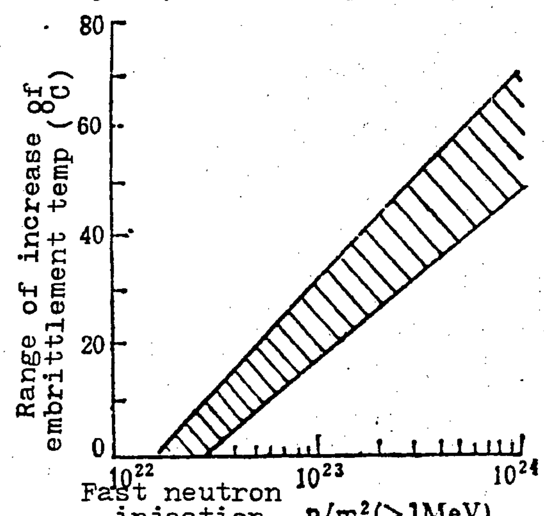

Figure 5. Increase of brittle-transformation temperature of A533-B steel (containing 0.05 percent to 0.10 percent copper) due to irradiation of fast neutrons at 290°C.

zirconium cladding due to dimensional change and lack of cooling. This is an important reason for reduced power and even shut-down of reactors. It appears that searching for structural materials that are more resistant to high temperature, corrosion, and radiation, and are high in strength and lower in creep is still our goal.

2.2 Stress Analysis and Thermoelasticity-Plasticity Problems

Many large components of a nuclear power plant, such as pressure vessels and steam generators, are operated under high temperature and pressure. In addition to the effects of high temperature and pressure, the various pipes are also affected by the dynamic response of flow-induced vibrations. In order to analyze the mechanical stress, thermal stress (including stress concentrations), and dynamic stress, knowledge about the temperature field, material phase transition, residual stress and thermal conductivity is needed. Control analysis of thermoelasticity and plasticity must be performed. Techniques in this area are relatively mature; the main analysis techniques are analytical methods, numerical methods, and experimental methods.

2.3 Fatigue Analysis

Fatigue problems in nuclear power plants may be divided into two types. The first type is plastic fatigue caused by external mechanical forces; an example is fatigue damage to pipes and the safety shell due to flow-induced vibration and wind-induced vibration. The second type of fatigue is thermal fatigue, especially low-cycle thermal fatigue caused by temperature changes and thermoelastic variations. For example, when a pressure stabilizer is operating, the thermal stress caused by temperature changes is of the low-stress, high-cycle type. When the reactor is shut down, or started, or when reactor power is changed, the cyclic stress experienced by pressure vessels and pipes is of the high-stress, low-cycle type; this type of fatigue is called low-cycle thermal fatigue. Plastic fatigue has been extensively studied by researchers, but thermal fatigue has not been adequately investigated. Shuji Taira[2] et al. in Japan have pointed out that under equivalent test conditions and thermal cycles, the number of cycles to fracture due to thermal fatigue and due to low-cycle thermal fatigue are basically the same. Therefore, as long as the start-ups and shutdowns are not very frequent and do not exceed the specified number, there is usually no need to conduct separate low-cycle thermal fatigue analysis.

Current fatigue analysis methods still use the Palmgrem-Miner linear damage accumulation criterion:

$$\sum_{i=1} \frac{n_i}{N_i} \leqslant \eta, \quad \eta = 0.1—1.0 \qquad (1)$$

where n_i is the number of cycles of a certain stress level and N_i is the number of cycles leading to fatigue damage at that stress level. Topics of interests include the variation of N_i at different radiation level and fracture criteria for random fatigue (including low-cycle thermal fatigue).

2.4 Fracture Analysis

A nuclear power plant has large components and tens of kilometers of pipes. In the casting, solidification and machining processes and in the installation and welding of the components, it is very difficult not to leave any incipient cracks. These components must be analyzed with the theory of fracture mechanics. Fracture analysis and monitoring technology for cracks have become active research topics in nuclear power institutes. Most of the structures used in nuclear power plants are made of high-toughness, medium- and low-strength steel. Linear elasticity theory is not suitable for the fracture analysis of these components; instead, elastoplasticity fracture theory should be used. In recent years, EPRI and DOE in the United States, CEGB in England, and the Chinese Academy of Sciences and Qinghua University in China have individually and cooperatively conducted systematic analysis of elastoplastic fracture. A set of engineering methods have been developed and the methods are quickly applied to the design of nuclear power structures.[7] Many good research topics still remain, however, including fatigue crack propagation, stress corrosion, fracture dynamics, and crack monitoring and control.

2.5 Wind-Pressure and Vibration Problems and Windproofing Design

Three of the eight large cooling towers of the Trawsfynydd power plant built in 1965 in the UK collapsed in strong wind; this prompted the concern of mechanical experts in the world.

Containment buildings and cooling towers are tall structures. The Qinshan power plant and the Daya Bay power plant on the southeast coast of China often see the fury of typhoons or even a tornado. These tall structures must be able to stand force-11 strong winds over the long term. For a tall building in a strong wind, in addition to the static deformation caused by the wind pressure, wind vibration may also occur for the following reasons: 1) vibration caused by the turbulence and gusts of the winds, 2) vibration caused by the turbulence and vortex generated by the building itself, and 3) the negative attenuation effects of the aerodynamics.

Wind vibration can cause structural fatigue, instability and failure. Since the periods of the self-oscillations of the buildings are in the seconds, several hours of strong wind can cause more than a million oscillations. If the maximum stress exceeds the fatigue limit, the structure will fail. [passage omitted]

There are two types of wind-pressure and wind-vibration experiments: field observation and wind-tunnel simulation.

Problems of interest are simulation of hurricanes, accurate measurements of τ and ξ, effects of roughness of the buildings, and probabilistic and statistical investigations of the pulse velocity spectrum and wind vibration.

2.6 Safety Analysis of Nuclear Power Plants in Earthquakes

Research and testing have shown that the natural frequencies of almost all building structures and reactor containment vessels are contained in the highest energy section of the earth surface seismological reaction spectrum. With the repeated occurrence, randomness and highly destructive nature of earthquakes, dangerous dynamic loading by earthquakes is a major concern in the design and site selection of nuclear power plants. The earth surface acceleration recorded by a seismometer during a quake (such as a time trace of the horizontal acceleration $d^2x_o(t)/dt^2$) is not suitable for direct applications; the most convenient data to use are the reaction spectra. [passage omitted]

The strength with which an earthquake affects a building structure is called the intensity. So far there has not been a unified method for the quantitative classification of intensity. Most countries use the acceleration equivalent as a standard. Let the maximum earth surface acceleration be a and the acceleration due to gravity be g, then $k = a/g$ is known as the earthquake coefficient. In China, a level-8 earthquake has a k value of 0.2, and the k value doubles for each increment of the 12 levels of the earthquake intensity. The designed earthquake intensity for nuclear power plants is 8.

In an earthquake, there are two concerns in the response of the foundation: 1) stability of the earth embankment, dam, and side slope, and 2) liquification of the foundation. The building sites of most nuclear power plants are selected to be on rocky grounds with high hardness and dynamic shear modulus in order to avoid foundation liquidation. The foundation of the Daya Bay nuclear power plant has a dynamic modulus of elasticity of 20-30 x 10^4 kg/cm^2.

In an earthquake a building structure is basically forced to vibrate. Its response depends not only on the motion of the earth surface (such as the horizontal acceleration $d^2x_o(t)/dt^2$, but also on the natural frequency, the vibration mode and the damping of the structure. The periods of the main peaks in the response spectrum of the surface acceleration are concentrated in the 0.1-2.5-sec range. Unfortunately, the characteristic periods of the fundamental and lower order harmonics of most buildings and structures are also in this range, leading frequently to a large response in the buildings during earthquakes. Because of the inertial forces caused by the acceleration of the various points on a structure, the structure is under the action of shear and torque. Together with the violent oscillations the structure may be experiencing, failures may occur.

There are several methods for computing the earthquake response:

2.6.1 Static Method

The structure is assumed to have the same acceleration as the ground (rigidity assumption) and the basis for determining inertial force is a = kg.

2.6.2 Modified Static Method[8]

In this method the acceleration characteristics of the ground and the dynamic characteristics of the structure are both considered. Based on a statistically obtained standard response spectrum, the acceleration of the structure is given by

$$a = k \times \beta(T) \times g \quad (12)$$

where g is the acceleration due to gravity, k is the earthquake coefficient, and $\beta(T)$ is the dynamic coefficient and a function of the natural period T of the structure. Figure 7 shows the variation of $\beta(T)$ with the natural vibration period of the structure for four different foundations. For foundation II with a period of 0.3 sec, we have:

$$\beta(T) = \begin{cases} 3, & (T < 0.3 \text{ s}) \\ 0.9/T, & (0.3 < T < 1.8) \\ 0.5, & (T > 1.8) \end{cases}$$

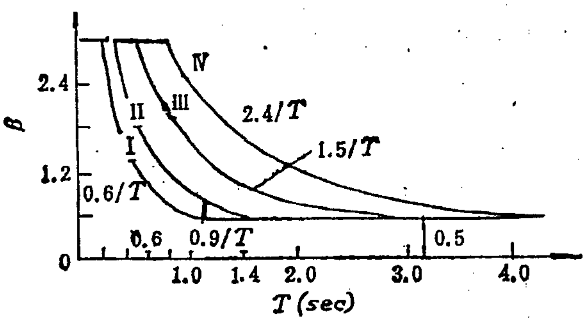

Figure 7

2.6.3 Dynamic Analysis Method

The modified static method is more suitable for single-point-mass systems. Real structures such as beams, plates, and frames are not single-point masses; their forced oscillations have different modes and the magnitude and phase of acceleration at different points on the structure are different. For these cases Eq. (12) can no longer be used and dynamic analysis methods are required. These include the direct integration method, the vibration-mode combination method, and the method for finding the maximum response from the average response spectrum. [passage omitted]

In addition to the above three methods, there are also the finite-element method and probabilistic analysis method.

In the earthquake analysis of containment and cooling towers, the following assumptions may be made for simplification: 1) the foundation is rigid, 2) the building may be described by a finite-beam model[10] or a shell model.[11] For the containment vessel, calculated results using the finite-beam method and the finite-element method are compared;[10] the distribution of the first mode and the bending moments are quite close.

2.7 Impact on the Containment Building by Aircraft

The concern of protecting the reactor from falling objects is basically a concern over aircraft impact. A test, shown in Figure 9, was performed. A 43-meter-long, 127.5-ton Boeing 707-320 flying horizontally at 103 m/s hit the containment building of a nuclear power plant horizontally at a height of 20 m. The impact time was 0.33 sec and the wing that weighed 38.6 tons fell off at an impact length of 22.0 m. In order to assess the impact loading of the aircraft on the containment building and the dynamic response of the containment building, Riera[12] assumed the situation depicted in Figure 10.

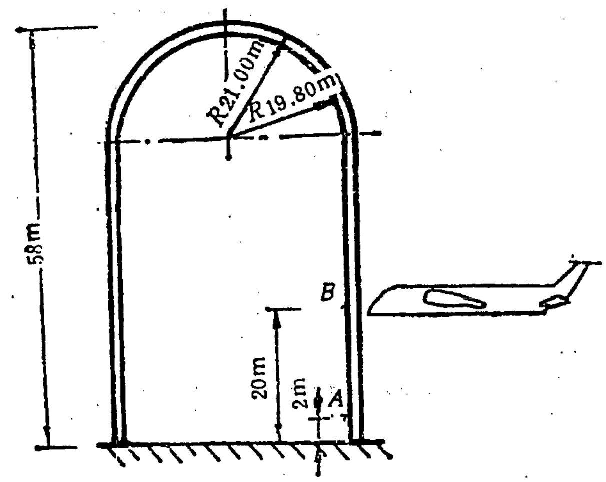

Figure 9

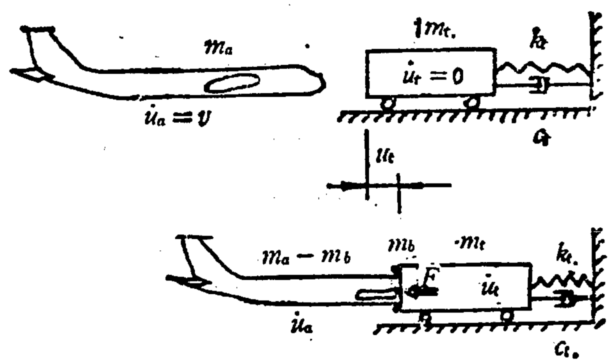

Figure 10

2.7.1 The containment building is a deformable target with a concentrated elastic (or elastoplastic) stiffness of k_t, a concentrated mass of m_t, and damping coefficient of C_t.

2.7.2 The aircraft is modeled as a continuous rigid plastic model (the Riera model).

2.7.3 The aircraft is crushed only on the cross-sectional plane close to the target and the crushed part becomes part of the accumulated mass of the containment building. The critical yield load causes the undamaged part to slow down.

Based on the mass distribution of the aircraft and the impact test results, the force-time curve of the aircraft (Figure 11) can be obtained by the Riera method. Under such an impact loading, the response spectrum of point A on the containment building is shown in Figure 12 as a solid line. Also shown is the response spectrum of the point for a level-8 earthquake with a horizontal acceleration of 0.21 g. As can be seen, in terms of acceleration, the earthquake induces mostly low-frequency responses and the aircraft impact induces mostly high-frequency responses. Therefore, if a lower-order-vibration-mode model or the beam model may be used in earthquake analysis, then the structure must be modeled with more detail. Higher-order vibration modes of 200 Hz should be included, and a shell model instead of the beam model must be used.

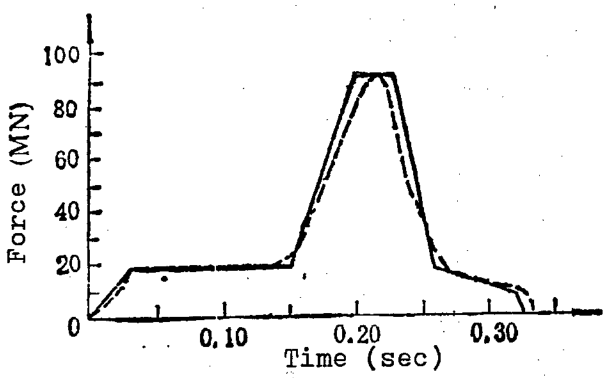

Figure 11. Force-time curve for Boeing 707-320 impact. Mass of aircraft = 127.5 tons, impact area = 37.2 m^2, impact velocity = 103 m/s, solid line: polygon approximation, dashed line: Riera theory.

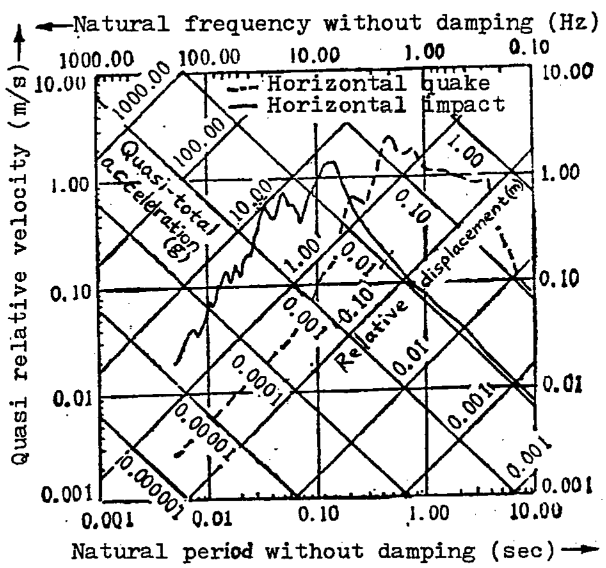

Figure 12. Horizontal response at point A on containment building (with 0.5 percent damping).

2.8 Coupled Effects

Structures in a nuclear power plant experience a complex environment of high temperature, high pressure, corrosion, radiation, pressure flow, hurricanes, earthquakes, and impacts. The coupled effects of these factors must be considered. A structure that is safe under the action of individual factors acting alone may not be safe when some of the factors are acting together. Topics for quantitative study are:

2.8.1 Coupling of stress and corrosion. Up to 1985 there have been more than 3,000 incidents involving stress corrosion of PWR steam generators.

2.8.2 Coupling of stress and temperature. At high temperatures, a helium-gas bubble may form in stainless steel, which can lead to serious embrittlement and fracture.

2.8.3 Coupling of radiation and fatigue. Since radiation degrades the toughness of the material, it may accelerate fatigue fracture and failure.

2.8.4 Coupling of pressure flow and dynamic force. Pipes experience pressure flow and its associated problems of flow-induced vibration, water hammer and cavitation erosion.

2.8.5 Consideration should also be given to the combined effects of earthquake, strong wind, pressure and high temperature.

2.9 Failure Analysis

Failure analysis is a new discipline developed in the last 10-20 years. Analysis of reactor failure is of great importance. There are many failure-analysis centers across the United States. For example, failure analyses were conducted as soon as the Three Mile Island accident occurred. By conducting failure analyses, similar incidents may be prevented in the future. In China we do not yet have special organizations for conducting failure analysis and certain incidents occur repeatedly. Such conditions are absolutely unacceptable in the development of nuclear power. We should start establishing special organizations for failure analysis as soon as possible in order to strengthen the ability to monitor and forewarn incidents.

Failure analysis can be divided into passive analysis and active analysis. In engineering most failure analyses are passive; fatigue theory, hydrogen embrittlement, stress corrosion, and fracture mechanics are all advances made through passive failure analysis. In nuclear power, active failure analysis should be used as much as possible so that accidents may be eliminated in their incipient stage.

3. Conclusion

As the nuclear power industry develops in China, new topics in mechanics will appear. We should improve our research and experimentation in mechanics in order to contribute to new advances in China's nuclear power industry.

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5MW District-Heating Reactor Uses Hydraulic-Drive Control Rods

40130124 Beijing LIAOWANG in Chinese No 31, 31 Jul 89 pp 25-26

[Article by Ma Xuquan [7456 2700 3123] and Huang Wei [7806 1218]: "Exploring the Secrets of Nuclear Energy and Its Peaceful Uses—Marking Completion of China's First Low-Temperature Nuclear Heat Supply Reactor"]

[Text] How can we alleviate and solve the energy resource shortage? One new route all the world's nations are exploring is developing nuclear power. Nuclear power is the only mature substitute energy resource. In 1981, Qinghua University's Nuclear Power Technology Institute finished transforming an operational experimental swimming-pool reactor into a low-temperature nuclear heat-supply reactor [i.e., a district-heating reactor] to provide heated air to three institute structures with excellent results. This project was included in the Seventh 5-Year Plan as a "focus within a focus" project.

I.

Not long ago, the Qinghua University Nuclear Power Technology Institute reported some gratifying news: after many years of work, installation and debugging of China's first low-temperature nuclear heat-supply reactor we designed and built ourselves has been completed and the reactor is operating normally. Completing it was a breakthrough in nuclear energy and its peaceful uses in China and it has entered the ranks of advanced world standards.

China's top nuclear power expert, Wang Dazhong [3769 1129 0022], director of the Qinghua University Nuclear Power Technology Institute, introduced the situation in this area. He said that when the peaceful use of nuclear energy is mentioned, everyone thinks first of nuclear power plants. Indeed, nuclear power reactors, which have an industrial scale and bring prosperity to mankind, are mainly used to generate electricity. A new member, though, has joined the multitude of nuclear power reactors: it is the low-temperature nuclear heat-supply reactor for centralized heat supply in urban areas. Data show that compared to burning coal, nuclear heat supply has advantages like saving coal, lower-cost heating, no environmental pollution, and so on. Nuclear heat supply costs 30 percent less than boiler heat supply. Moreover, compared to a nuclear power plant, a nuclear heat-supply reactor has advantages like simpler equipment, shorter construction times, smaller investment, and so on. Although there are now 30-plus low-temperature reactors in the world, most are used to generate power while providing excess heat. Over ten nations including the Soviet Union, United States, the FRG, France, England, and others have studied low-temperature nuclear heat supply but most are still in the experimental stage. Canada has completed and placed into operation a low-power, low-temperature swimming-pool nuclear heat-supply reactor. Its parameters are low and it has not attained an industrial scale. It is apparent that international work began rather late in this area, so China may be able to catch up with advanced international levels.

China's low-temperature reactor operates at a low temperature (198°C), low pressure (15 bar), and low power density. It uses an integrated natural cycle structure, has no rotating valves, does not rely on an external power source for cooling, and so on, and it has an intermediate isolation loop, so it is simple and reliable. Deserving special mention is that the key component in this reactor, the control-rod drive system, uses a hydraulic [water-powered] drive arrangement. It is different from the electromagnetic and mechanical drive systems or hydraulic [pressurized-liquid] drive systems now used in reactors. This drive structure avoids technical problems from high-temperature, high-pressure sealing in power reactor control drives, so it has advantages like structural simplicity, safety, long life, low cost, and so on. Its application can simplify the structure of reactor tops, reduce reactor heights, and prevent nuclear leaks and other accidents.

Pointing to the design blueprint hanging on the wall, Wang Dazhong said emphatically that "after the Chernobyl Nuclear Power Plant accident in the Soviet Union, people turned colors when talking about nuclear power. Thus, the 5 MW low-temperature nuclear heat-supply reactor we designed put safety first. This 5 MW low-temperature reactor is the world's first reactor with hydraulic [water-powered] drive-control rods."

II.

Reporters were fortunate enough to see the final installation of the reactor's internal components before the low-temperature reactor was sealed.

In the reactor building, the shouted installation directions, sounds of welding sparks, and S&T personnel and laborers working on installation blended together and the tense installation work went according to procedure. Rows of several hundred uranium rods used as fuel were placed in sequence into the reactor core surrounded by cooling water. The exterior is an enormous safety pressure screen and safety vessel. The exterior of the reactor looks like a big chicken egg standing on end.

Deputy senior engineer Dong Duo [5516 6995], who was on site directing the installation, discussed the reactor construction process with the visitors. He said that construction of this experimental reactor project, which was directed by Professor Wang Dazhong, began in March 1986. Civil engineering construction was completed smoothly at the end of 1987. Installation of 17 technical systems was completed in Spring, 1989. In 3 years, instructors and employees in the Nuclear Power Technology Institute finished 13 important scientific research topics on the low-temperature nuclear heat-supply reactor, wrote a 2.5 million character installation report and related documents and submitted them to the State Nuclear Safety Administration, and used the Changchun No 1 Automotive Works as a base point for feasibility research on a large-scale commercial low-temperature nuclear heat-supply reactor.

Final hoisting of the top seal for the reactor's internal components came on 15 April 1989. That day, institute leaders and many S&T personnel and workers went early to the reactor to prepare for installation. The precision components to be hoisted were prepared, some as heavy as 4.5 tons and some as light as silk, and there were quite a few small pipes and valves which required precision welding. Thus, lifting and installing them was very hard and not even the smallest of errors could be permitted. No one rested or ate while installing. They fought for 13 solid hours and eventually completed their tasks smoothly at 4 pm on 15 Apr 89.

III.

Research, design, construction, and installation of the 5 MW low-temperature nuclear heat-supply reactor involved the condensed blood and sweat of the over 600 instructors and employees in the Qinghua University Nuclear Power Technology Institute.

The reporters heard a moving story filled with fighting for progress and the spirit of seeking truth from science.

The infirm Wang Dazhong had overall responsibility for research on the low-temperature nuclear heat-supply reactor. He did much intensive and detailed organization and technical guidance work in the program selection and experimental construction stages. In late 1988, while participating in a discussion on S&T cooperation in West Germany, fatigue put him in the hospital with heart disease and the doctors let him rest for a month, but he went back to work after resting for just 1 day when he returned to China. At crucial times during reactor core installation, he usually ate and lived at the work site together with the workers.

Institute deputy director Lin Jiagui [2651 1367 2710] is a female comrade over 50. She spent several winter and summer holidays over the last 2-plus years working at the institute and often did not go home, staying on site with everyone day after day. During final installation work, she gave on-site direction for 48 straight hours. She lost her voice and her face was thin and pallid, but she did not rest until everyone warned her. Engineer Dong Duo, who is suffering from cancer, continued to work on the front line after two operations and threw himself into leading the S&T personnel to attack key technical problems.

Many institute S&T personnel did full-scale experiments with key equipment and technologies to complete key experiments and the construction design. For example, S&T personnel responsible for studying the control-rod hydraulic [water-powered] drive system gave up many vacations and holidays without pay for over 4 years to work overtime on building five platforms and doing cold-state and hot-state experiments and comprehensive experiments, eventually moving this system up to advanced international levels.

Relevant experts said in evaluation that the low-temperature nuclear heat-supply reactor has vast prospects in north China. North China has 175 large and medium-sized cities which must heat more than 1.25 billion cubic meters every winter. It has been projected that with a rather long period of effort, erecting several low-temperature nuclear heat-supply reactors in north China would make the atmosphere above these cities a deep blue sea and the forests denser and more luxuriant. Nuclear power can warm people in the winter and cool them in the summer. Nuclear energy will bring substantial prosperity to the people and become an indispensable new energy resource for society. Completion of the 5 MW low-temperature nuclear heat-supply reactor is a strong first step toward this beautiful era.

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